Overview on the preliminary geodetic network for SPIRAL2 process installations at GANIL

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OVERVIEW ON THE PRELIMINARY GEODETIC NETWORK FOR SPIRAL2 PROCESS INSTALLATION AT GANIL

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Abstract

The SPIRAL2# project located at the Grand Accélérateur National d'Ions Lourds (GANIL facility - Caen, France) is now under construction. This project aims at delivering rare (radioactive) isotope beams with intensities not yet available with presently running machines. An important aspect of this project is that it is foreseen to deliver up to five different beams in parallel to the users.

This paper is focused mainly on the preliminary geodetic network for the SPIRAL2 process installation. The positioning of the process and by extension of the buildings is subject to an important constraint due to future connection of the radioactive beam line to the existing accelerator complex.

To reach the required accelerator performances, a geodetic surface network made up of concrete monuments around the construction is linked to the local network of the existing accelerator [1]. The surface network has been transferred to the slab of the accelerator tunnel at -2 level (-9.50 m) in order to define the underground reference network for the process setup.

Final goal of the geodetic network is to allow the alignment of the process accelerator components [2] [3] [4] [5] [6] according to design within required tolerance. Various tolerances objectives will be given.

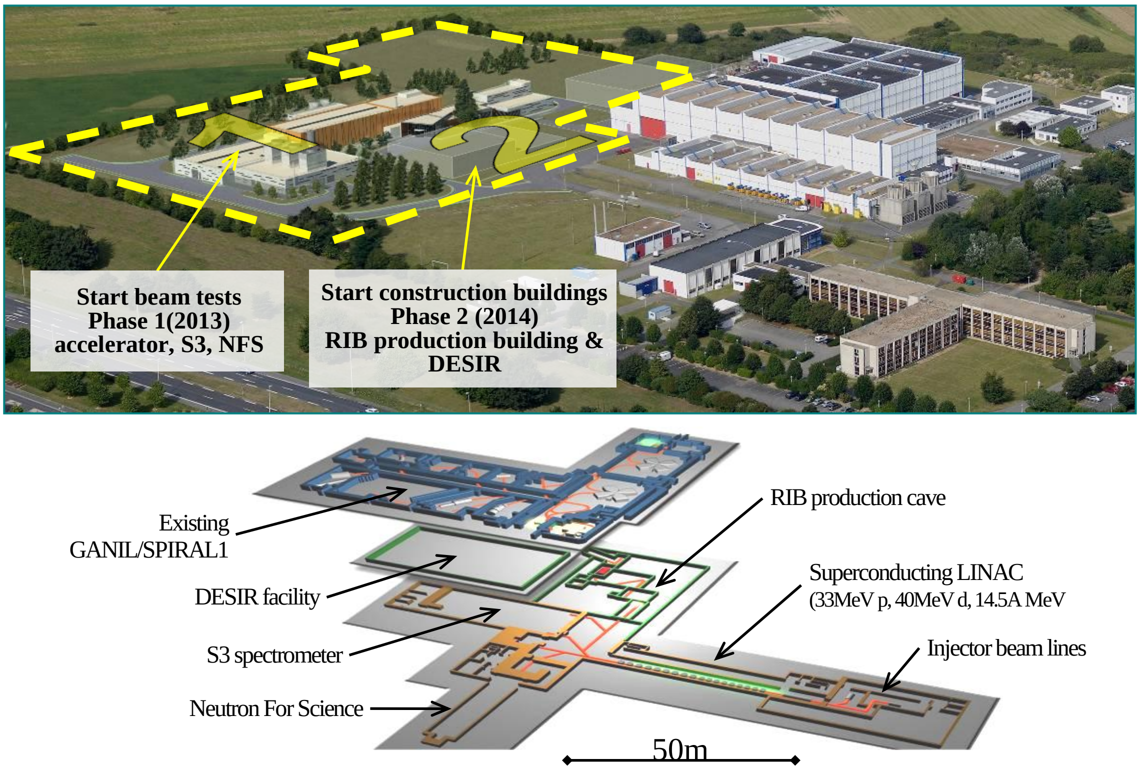

Figure 1: Layouts of the SPIRAL2 accelerator complex and existing GANIL facility (dark blue)

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** GANIL: Grand Accélérateur National d'Ions Lourds [Large-scale national accelerator for heavy ions] - CEA/DSM-CNRS/IN2P3

SPIRAL2 : Système de Production d'Ions Radioactifs Accélérés en Ligne [production system of on-line accelerated radioactive ions]

INTRODUCTION

SPIRAL2 is a facility intended for the production of new beams of stable and radioactive ions at GANIL. The SPIRAL2 facility (see Fig.1) is based on a high-power superconducting driver LINAC which delivers a high-intensity, 40-MeV deuteron beam, as well as a variety of heavy-ion beams with mass-to-charge ratio equal to 3 and energy up to 14.5 MeV/u. The driver accelerator (phase 1) will send stable beams to new experimental areas and to a cave (phase 2) for the production of Radioactive Ion Beams (RIB). The beam tests of Phase 1 will start in 2013 at GANIL.

Fast neutrons will be produced from the break-up of the 5 mA CW deuteron beam using a carbon converter. Up to 10^{14} fissions/s will be induced in a uranium carbide target. The extracted RIB will then be accelerated to energies up to 20 MeV/u (typically 6-7 MeV/u for fission fragments) by the existing CIME cyclotron.

The surveying and alignment activities at GANIL are under the responsibility of a three people team in the Techniques of Physic Department. The surveyor team supports and interacts with physicists and engineers working on any specific projects, from the detailed design study, to the final alignment of components on the beam line.

PROCESS ALIGNEMENT STRATEGY

An indispensable element of the survey is the geodetic network made up of a series of stable points at strategic positions. It defines the reference coordinates for the facility. Discussions took place during the detailed design study in order to define the best strategy to choose for the process implementation and by extension of buildings [7].

THE GEODETIC SYSTEMS

The use of geodetic systems is the basis for all spatial layouts whether small or large. On the SPIRAL2 project, our objective is to install the accelerator process geographically at the right place on the GANIL site and thereby guarantee the future connection of the multicharge radioactive beam transport line (phase 2 of the SPIRAL2 project) to the CIME cyclotron of the existing installations.

The only way of guaranteeing that the entire installation is homogeneous is to have a geodetic system [8] of millimetric precision around the future buildings connected to the cartesian coordinate system of the existing accelerator network. For the requirements of the prime contractorship, this new network has also been connected to the national geodetic system.

The local system

The GANIL has a "local" geodetic system, created when the facility was built. All the beam lines are known in this geodetic system. It is used to align and position the functional components, both on the accelerators and on the experimental areas.

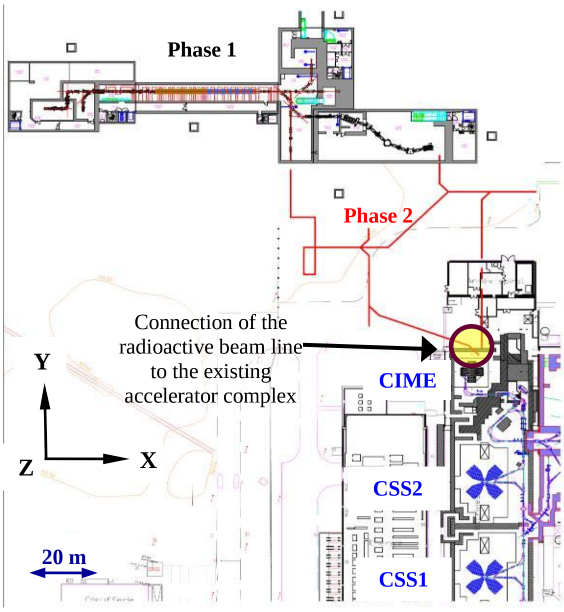


Figure 2: Figure showing the local system defined by the two cyclotrons CSS1 & CSS2

This local system is a Cartesian coordinate system defined by the centres of the two cyclotrons; CSS1 and CSS2 (see Fig. 2). These centres are represented by plaques on the concrete foundations supporting the cyclotrons at level -1 of the accelerator building.

Table 1: Coordinates of the points of the local geodetic system

	X (m)	**Y** (m)	**Z** (m)
Centre CSS1	500.000 00	200.000 00	20.000 00
Centre CSS2	500.000 00	229.015 38	20.000 00

Note that the Z coordinate of 20 m corresponds to the beam median plane at level 0.

The national geodetic system

A general topographic plan of the site was produced in 2003 and completed in 2007 (agricultural land at the North and east of the site).

This plan is expressed in the French national geodetic systems, whose characteristics are as follows:

- planimetry – Lambert 1 conical projection system*.
- altimetry – NGF IGN69 system #.

The work plans of the SPIRAL2 project (work site, earthworks, facilities) were produced on the basis of the

*Lambert 1: The Lambert conformal conic projection is a map projection frequently used in geodetics. In this conformal projection system, the meridians are concurrent straight lines and the parallels of the circle arcs centred on the point of convergence of the meridians.

NGF IGN69: The Nivellement Général de la France (NGF) (the French official reference datum) forms a network of altimetric markers distributed over metropolitan France, including Corsica, for which the IGN is now responsible. This network is currently the official reference datum in metropolitan France.

GANIL topographic plan. Consequently, these plans are expressed in the Lambert 1 and IGN69 systems.

"Connection" of the local geodetic system to the national geodetic system

The GANIL local system therefore had to be "connected" to the national system, so we know the relation between the two systems.

The project Cartesian coordinates are expressed in both geodetic systems: in the GANIL local system for the process requirements and in the Lambert 1 and NGF IGN69 system for the unique system requirements of the work and construction plans.

This operation, connection of the GANIL local system to the Lambert and IGN69 system, has several objectives:

- "recalibrate" precisely the work plans and the building plans to match our local system,
- simplify the process installation principle to guarantee the required connection of the multicharge radioactive beam transport line to CIME (see Fig. 2) by transferring reference points down to -9.50 m. The points were transferred using the durable surface geodetic network (see Fig. 4 & 7 - phase 1 and phase 2) indicated by concrete pillars.

PROCESS INSTALLATION

The process consists of all functional components of the beam lines in the accelerator and production buildings.

The operation consisted in marking the axes of the beam (Linac) and transport lines to the production area (LHE). This operation was carried out in two steps:

- Installation and calculation of a "surface geodetic network known in the local coordinate system (see Fig. 4).
- Installation of an underground topometric network at level -9.50 m (see Fig. 7 & 9) from the surface geodetic network. The final goal of this topometric network will be to align the process of phases 1 and 2.

Special safety measures

The worksite during construction can only be accessed after drawing up a specific health and safety protection plan (French PPSPS). The plan is then sent to the GANIL and SPIRAL2 safety engineers for checking, then submitted to the Health and Safety coordinator. A joint inspection of the site is organised before starting work.

Surface geodetic network

It is indicated by concrete pillars (see Fig. 3). This network takes into account firstly the land occupied by the worksite and earthworks area and secondly the final layout. This network consists of 6 pillars distributed near the future buildings (see Fig. 4). It will be used firstly to provide reference points to allow installation of the process at level -9.50 m and secondly as means to monitor movements of the buildings at level 0.

To plan for possible future extensions, these pillars will remain in position throughout the lifetime of the accelerator.

Figure 3: Pillar under construction and protective fencing around geodetic pillar

Determining the positions of the first order network geodetic pillars

The operation was carried out in two stages: installation of the pillar markers, then surveying of the pillars after construction. Given the size of the work area (about 3 ha) and the vegetation, use of GPS was recommended. These two operations were subcontracted.

The positions of the pillars prior to excavation were therefore determined using GPS measurements. Precision of ± 1cm is required. The GPS readings were taken by differential measurement using the coordinates of two points provided by the "Alignment" group (see Table 2). Their coordinates are known in the two geodetic systems. These points, located to the north of the current installations, are indicated by nails driven into bitumen.

After manufacture, the provisional Cartesian coordinates of the pillars were determined by tacheometric measurements. The precision requested is ±5.0 mm. Based on the service provider's data, we adjusted the four pillars of the two accelerator fundamental axes (Linac axis and LHE axis) as close as possible to the theoretical values using off-centred plates.

Table 2: Coordinates of the points taken as absolute reference to set up the geodetic network using GPS measurements

Number	Lambert 1		NGF	LOCAL SYSTEM		
	X	Y	Z	X	Y	Z
7032	403 545.982	171 876.646	57.942	554.350	298.542	17.968
7033	403 479.113	171 867.331	58.500	487.107	304.590	18.526

Geodetic pillars

The geodetic network was indicated by six cylindrical concrete pillars of height above ground 1.20 m and diameter 0.30 m. A cylindrical plate equipped with a Leica type socket mounted offset is sealed on the top end of the pillar (see Fig. 5). The natural movements of the land and those induced by the earthworks could randomly modify the positions and altitude of the pillars. To partially solve this problem, the pillars had to be anchored on a more geologically stable bed and isolated from the future infrastructures and their excavations (see Fig. 3). Wooden protective fencing has been erected to keep earthwork plant away from the site.

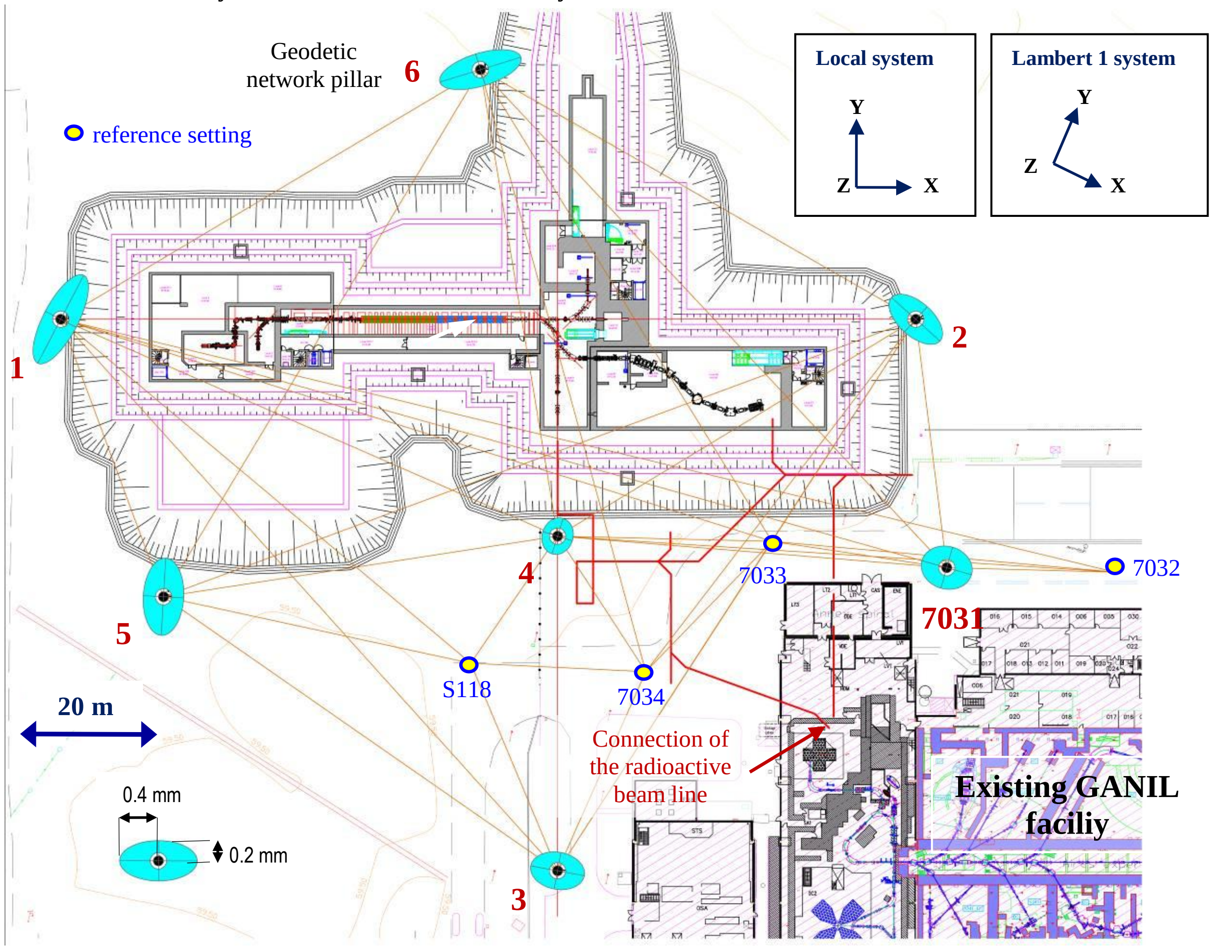


Figure 4: Surface geodetic network and the absolute error ellipses at June, 2011

Measurement of the "surface" geodetic network

The network was measured by tacheometric measurements using a TDA5005 tacheometer.

The top of the pillars is also equipped with a levelling marker consisting of a cone for a sphere of diameter 3.5". The altitude of these markers was determined by precision levelling using the optical level (NA2+micrometer). This levelling was connected to the GANIL altimetric system. A standard deviation of 0.08 mm was obtained throughout network.

The entire geodetic network was calculated. The four markers positioned outside the existing installations acted as reference points (points S118, 7032, 7033 and 7034). A total of 300 observations were made (angles and distances projected onto the horizontal plane). The standard deviations are calculated relative to the sigma a priori (equal to 1).

The calculations gave the following distribution for the distances reduced to the XY plane (see Fig. 6):

- mean residue: 0.12 mm for a 95 % confidence qinterval (-0.09, +0.09)
- standard deviation: 0.38 mm for a 95 % confidence interval (0.33, 0.46)

The calculations gave the following distribution for the horizontal angles:

- mean residue: 0.0 CC for a 95 % confidence interval (-0.8, +0.8)
- standard deviation: 3.4 CC for a 95 % confidence interval (2.9, 4.1)

The network was analysed with CERN software LGC and the following parameters: sigma a posteriori = 1.0

- significance level, for testing wi, alpha = 1.0 % or expressed as confidence level, (1-alpha) = 99.0%
- power of test, to determine nabla and delty, (1-Beta)=90.0%

The overall network reliability factor is equal to 0.2195

Figure 5: View of the upper section of a geodesic pillar

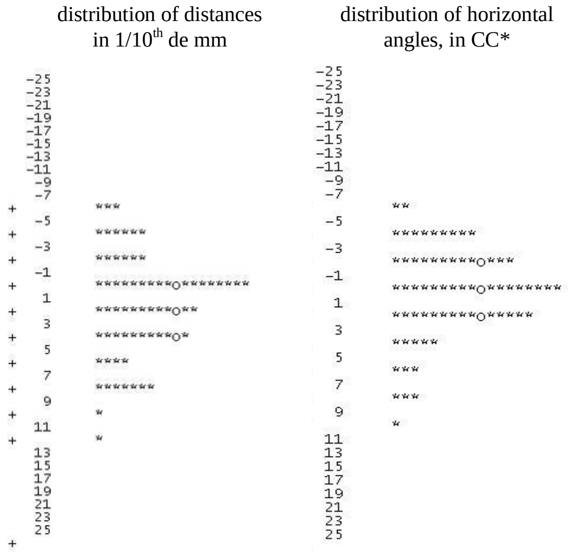


Figure 6: Distribution of distances reduced to the XY plane and distribution of horizontal angles

Table 3: Result of the calculation in Cartesian coordinates of the geodetic pillars

Pillar No.	**X** (m)	**Y** (m)	**Z** (m)	**SX** (mm)	**SY** (mm)	**DX** (mm)	**DY** (mm)
1	37.79855	348.23640	0.0	0.27	0.44	0.19	0.18
2	515.26920	348.23325	0.0	0.26	0.25	0.22	0.04
3	445.11160	239.83972	0.0	0.26	0.19	-0.09	-0.17
4	445.10967	305.60347	0.0	0.15	0.18	0.08	0.06
5	367.93259	293.69425	0.0	0.20	0.38	-0.07	0.13
6	430.00353	397.29607	0.0	0.40	0.20	0.29	0.17
7031	521.33469	299.41569	0.0	0.21	0.25	0.88	0.15

Table 4: Table showing the absolute error ellipses

Pillar No.	**SEMI-MAJ. (A)** (mm)	**SEMI-MIN. (B)** (mm)	**ORIENT. OF (A)** (grads)	**EIGENVALUES** MAX	MIN	**GEOMETRIC MEAN** EIGENVALUE
1	0.4873	0.1710	30.6000	0.237	0.029	0.083
2	0.3198	0.1671	346.5917	0.102	0.028	0.053
3	0.2673	0.1825	311.6178	0.071	0.033	0.049
4	0.1829	0.1518	19.2915	0.033	0.023	0.028
5	0.3804	0.1987	3.6900	0.145	0.039	0.076
6	0.4158	0.1610	80.9540	0.173	0.026	0.067
7031	0.2528	0.2096	17.5552	0.064	0.044	0.053

Transfer from the surface geodetic network to level -9.50 m of the accelerator building

The axes of the beam lines (Linac and LHE) were indicated on the concrete slab at level -9.50 m from pillars 1 and 2 of the surface geodetic network (see Fig. 7, Linac axis). A similar principle is used to transfer the high-energy line axis. This operation was carried out before the concrete slabs of the higher levels were cast (ceiling of Linac and beam transport rooms).

The axes are indicated by adjustable markers (see Fig. 8) sealed in the slab at predefined positions. These markers form the framework of the process topometric network. Their Cartesian coordinates were determined using the geodetic pillars of the surface network.

All process functional components will be aligned and positioned using this topometric network. The altitude of the beam axes of the primary lines in the accelerator building and the secondary lines in the production building is +10.50 m (GANIL local system).

*CC : CC is 1 dmgon or a second centesimal (1/10 000th grade)

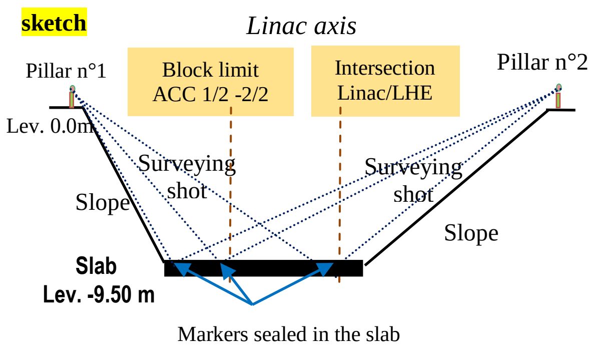


Figure 7: Sketch showing the installation principle of the process (Linac) axes at level -9.50 m

Installation of the room and process topometric network

The room and process topometric network installation started in July. The GANIL "Alignment" group will be responsible for indicating the positions of the markers on the slab and the walls. The laboratory “Heritage department” will handle the coring/drilling and sealing operations.

Coring of markers for the room and process topometric network

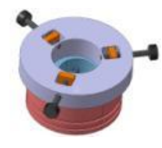
The work consists in drilling and coring the slab and walls to seal in the markers. The drilling or coring diameter depends on the type of marker to be installed. It is indicated below:

- Non-adjustable marker of diameter 50 mm in the slab for the building topometric network,
- Adjustable marker of diameter 76 mm in the slab for the process topometric network (vertically above the beam lines)
- Non-adjustable marker of diameter 19 mm in the walls for the room topometric network positioned at two different levels (1.50 and 2.50 m).

3D measurement of the topometric network

The markers transferred onto the slab at level -9.50 m indicate the Linac and high-energy line (LHE) axes. They have become the absolute reference for setting up the room and process topometric network.

adjustable marker XY inserted in its box
Ø 76 mm
Source: GANIL



marker adjustment tool
Source: GANIL

view of the marker position tracing template

non-adjustable marker,
Ø 50 mm
Source: HUBBS

wall marker , Ø 19 mm
Source: BRUNSON

Figure 8 : View of markers in the building and process topometric network

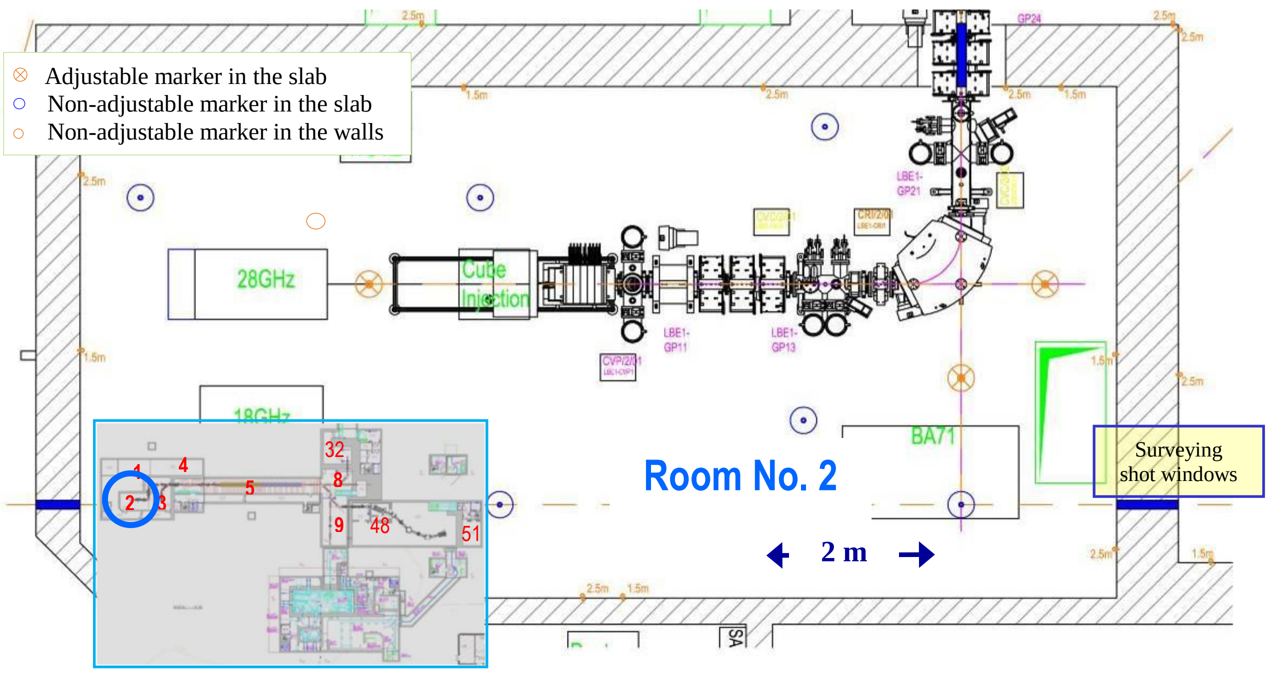


Figure 9: Figure showing the topometric network of room No 2

Measurement of the topometric network is made more complicated by the walls between the various rooms. Surveying shot windows were planned between the rooms during the building programming studies.

The recent acquisition of a new-generation AT 401 laser tracker will enable us to connect together the networks of the various buildings by implementing the instrument vertically above a point. The network will be calculated using Spatial Analyser software.

CONCLUSION

The GANIL "Alignment" group is currently preparing installation of the SPIRAL2 accelerator phase 1 process.

To install this process, and well before aligning a first functional component, a geodetic network connected with the local topometric network of the existing installations had to be set up around the future buildings. Using this geodetic network, we have recently been able to position markers on the main axes (Linac and High Intensity Line) to define the framework of the future network in the accelerator tunnel at level -2 of the buildings (-9.50 m).

The final measurements of the surface geodetic network were taken using a TDA5005 tacheometer. The error ellipses indicate values that are quite acceptable for measurement conditions no longer in laboratory but in the field. The results of this first step would suggest that it will be possible to connect the Radioactive Beam Transport line (phase 2 of the project) to the CIME cyclotron of the existing installations without too much difficulty.

The recent acquisition of a new-generation AT401 laser tracker will allow firstly measurement of the process topometric network and secondly 3D positioning of the accelerator functional components. This new instrument will therefore help us to reach the objectives set by the project.

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